Design of Integrated Mixed Technology Microsystems

Anantha Krishnan

Microsystems Technology Office
DARPATECH

September 2000

Technology Trends

- SYSTEM COMPLEXITY IS INCREASING !!

- DESIGN AND PROTOTYPING COSTS ARE INCREASING AT A GREATER RATE (TRIAL & ERROR APPROACH) !!

- INTUITION AND 'EXPERIENCE' ARE JUST NOT GOING TO CUT IT !!

NEED CAD TOOLS TO SIMULATE AND PREDICT SYSTEM PERFORMANCE BEFORE PHYSICAL PROTOTYPING IS DONE !!

Design Approach

Today, mixed technology "systems" are developed from the "bottom up" using many different components

SYSTEM

SUB-SYSTEM

COMPONENT

Ad-hoc Design, Research Codes, Single User Tools

Design Approach

Future mixed technology systems must be designed from the "top down" using a consistent set of requirements

SYSTEM

↓

SUB-SYSTEM

↓

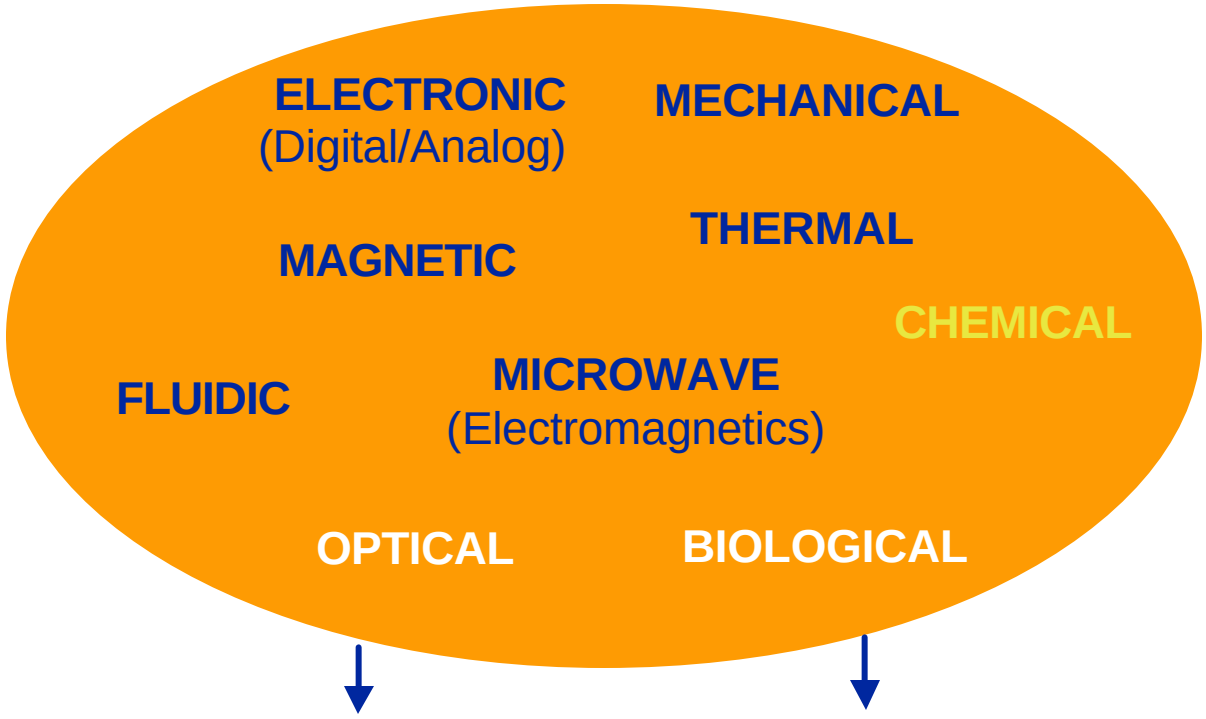
COMPONENT

Methodology, Design Rules and Checks, Multi-User Tools

Goal is to provide VLSI-like Design Tools for Integrated Mixed Technology Systems

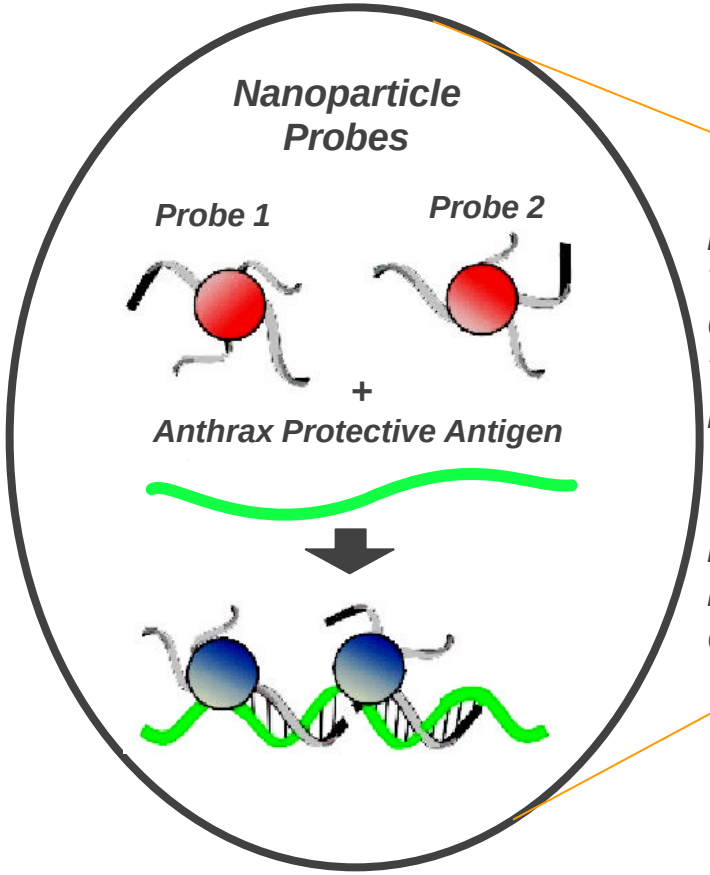
Integrated Microsystems

- Microsystem technology is much more complex due to interaction of mixed technologies - electronics, mechanics, optics, fluidics, chemistry, biology, …
- But same analogy holds : Microsystem-EDA essential for growth of **Integrated System** technology !



Adapted from David Nagel, Naval Research Laboratory

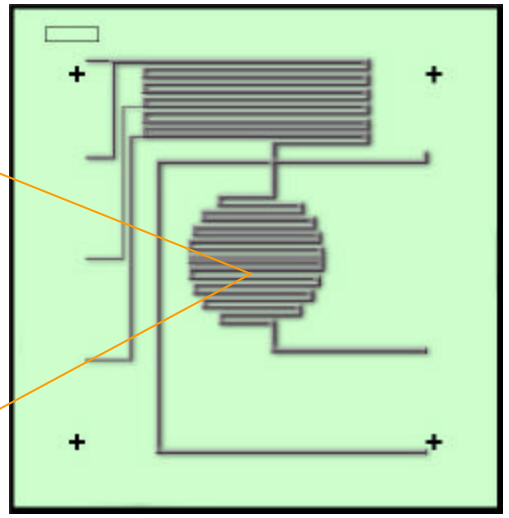
Biological/Chemical Sensor Systems



Bio-Molecular Transport, Chemistry and Transduction in Microsystems

Interfacing with Electronics, Mechanics, Optics, ...

Bio-Chip



Molecular Recognition

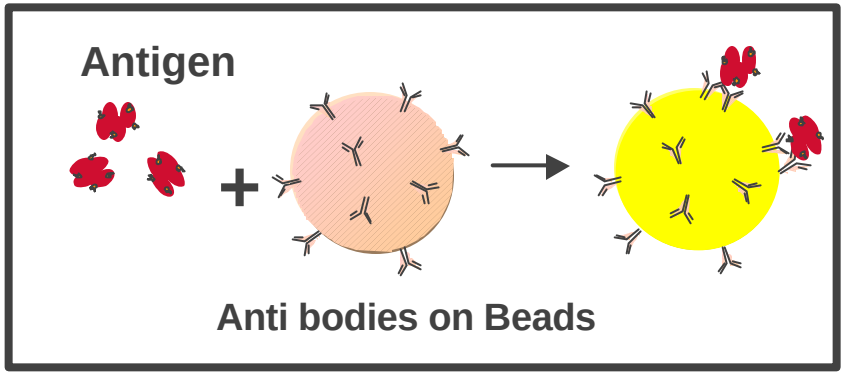
Electrical Signal

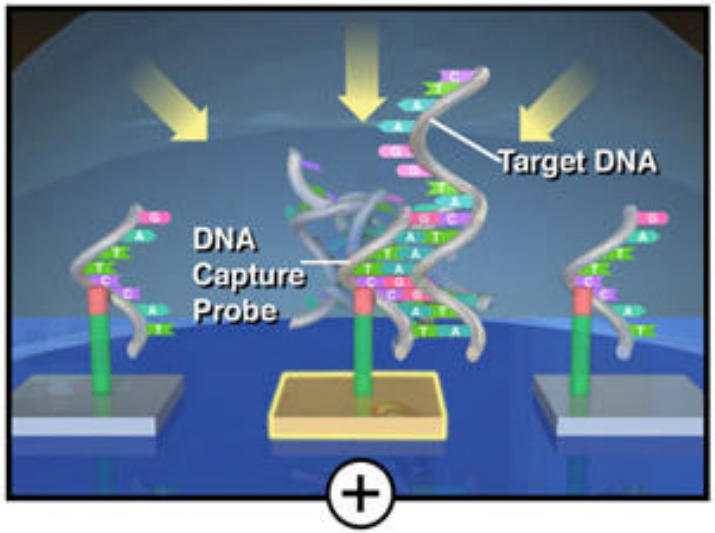
Optical Signal

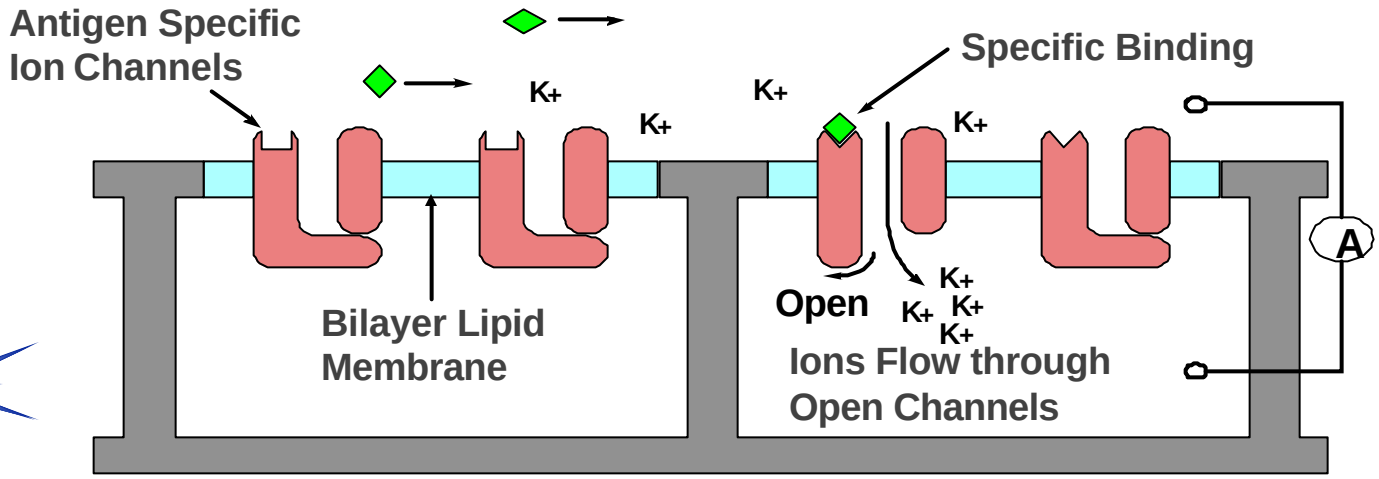
Mechanical Signal

Molecular Recognition

- **Development of models for bio-molecular interactions in microsystems**
  - **Time Scale of Process**

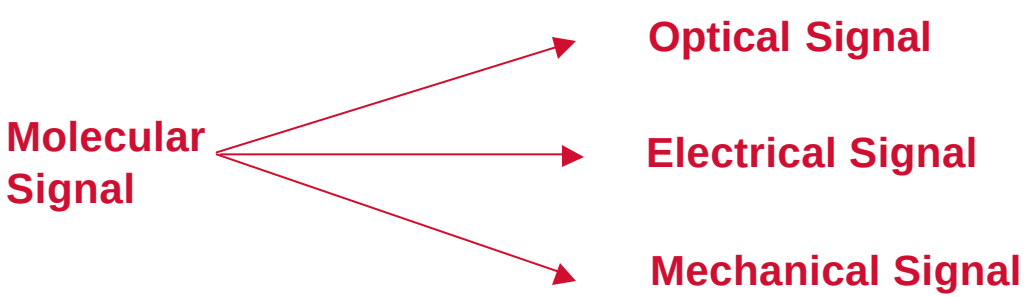


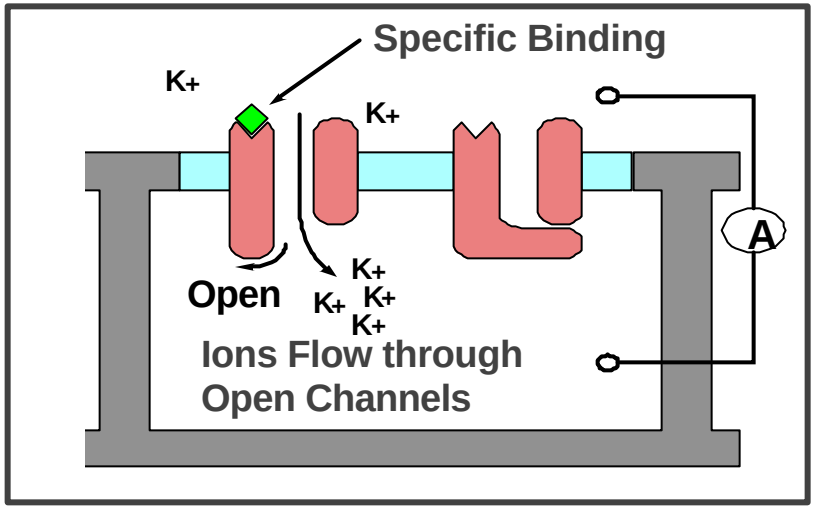


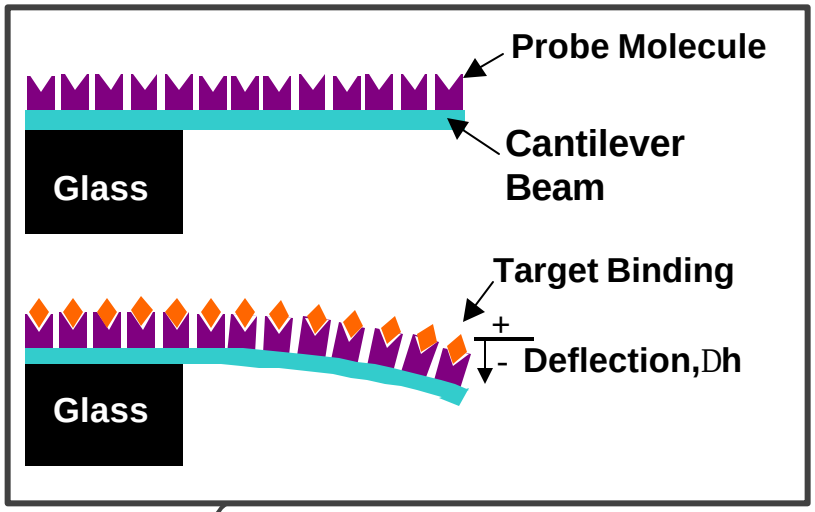


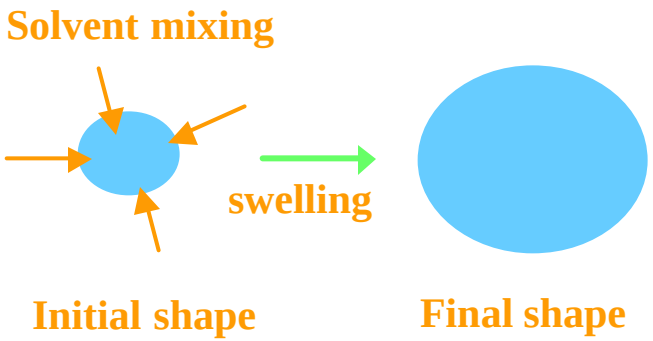
Signal Transduction

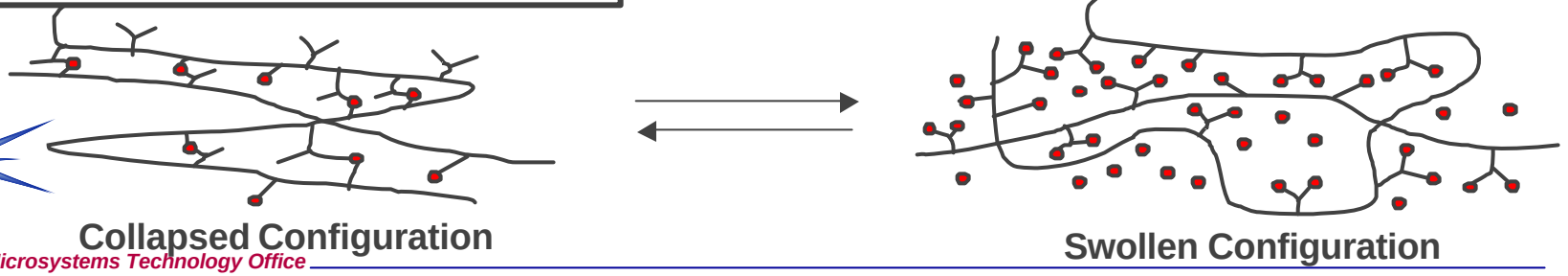
- Development of models for the transduction process





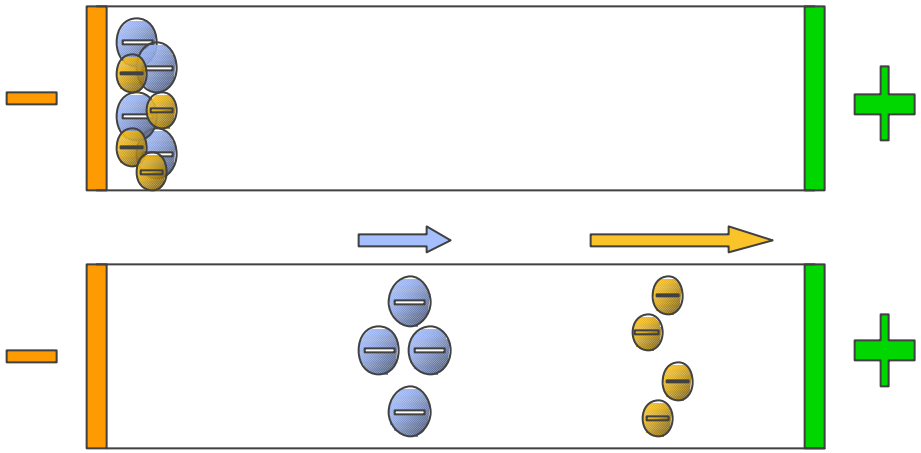




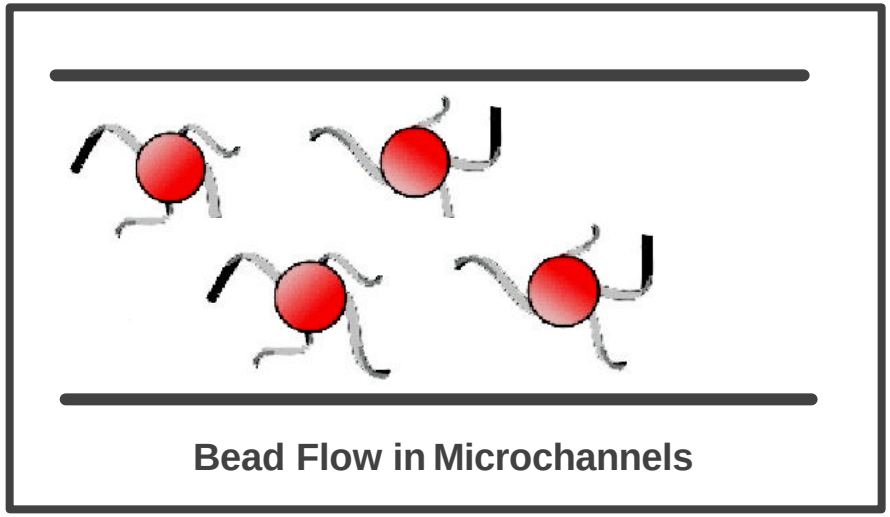


Microfluidics

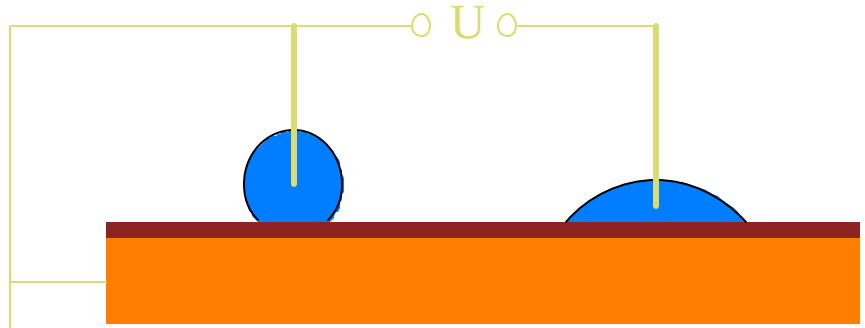
- **Models for Bio-Molecular and Fluidic Transport**



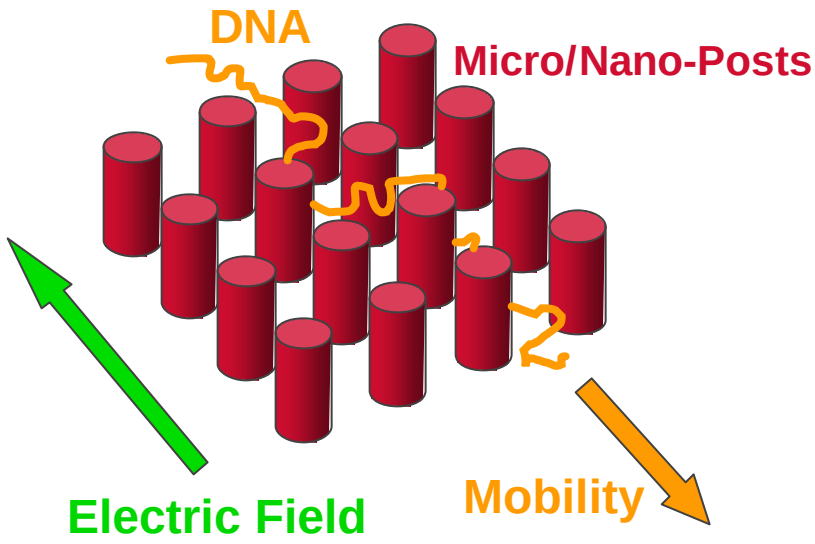
Electro-osmosis + phoresis



Bead Flow in Microchannels



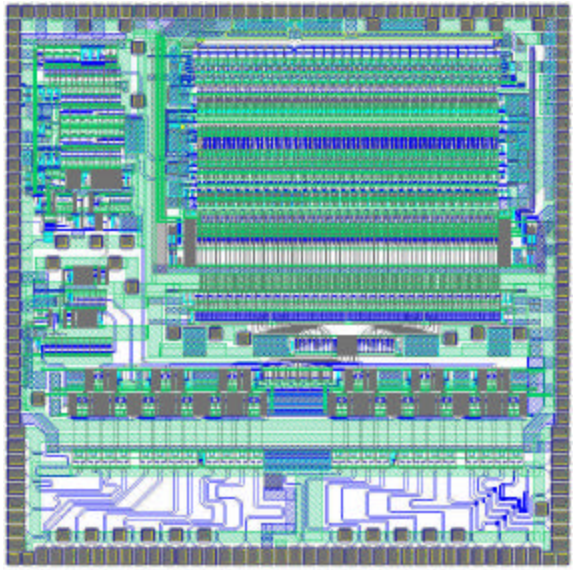
Surface Tension Driven Transport



Electronic and Photonic Systems

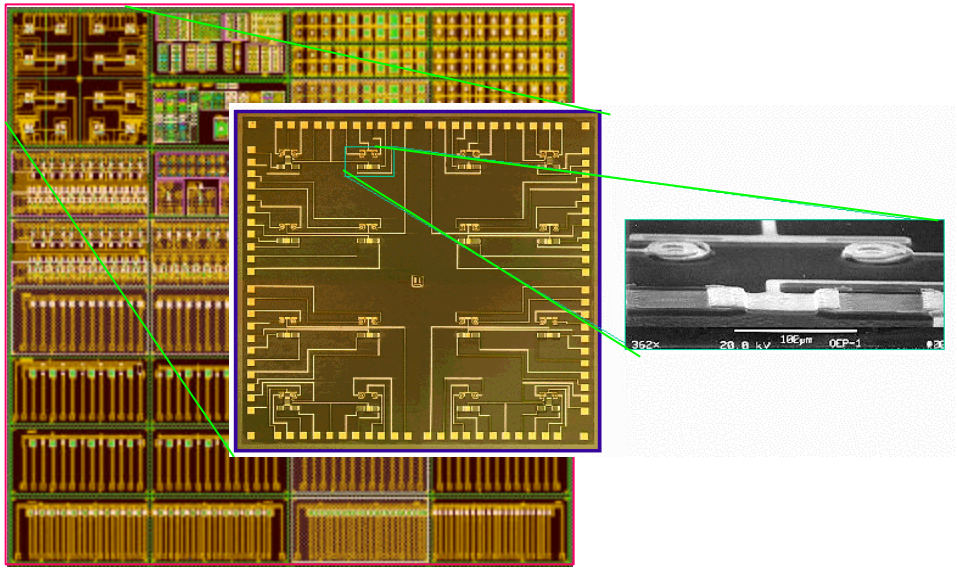
Mixed Signal (Analog-Digital) Systems

Advanced Digital Receiver Chip (A-D and D-A Converters)



Mixed Electronic/Photonic Systems

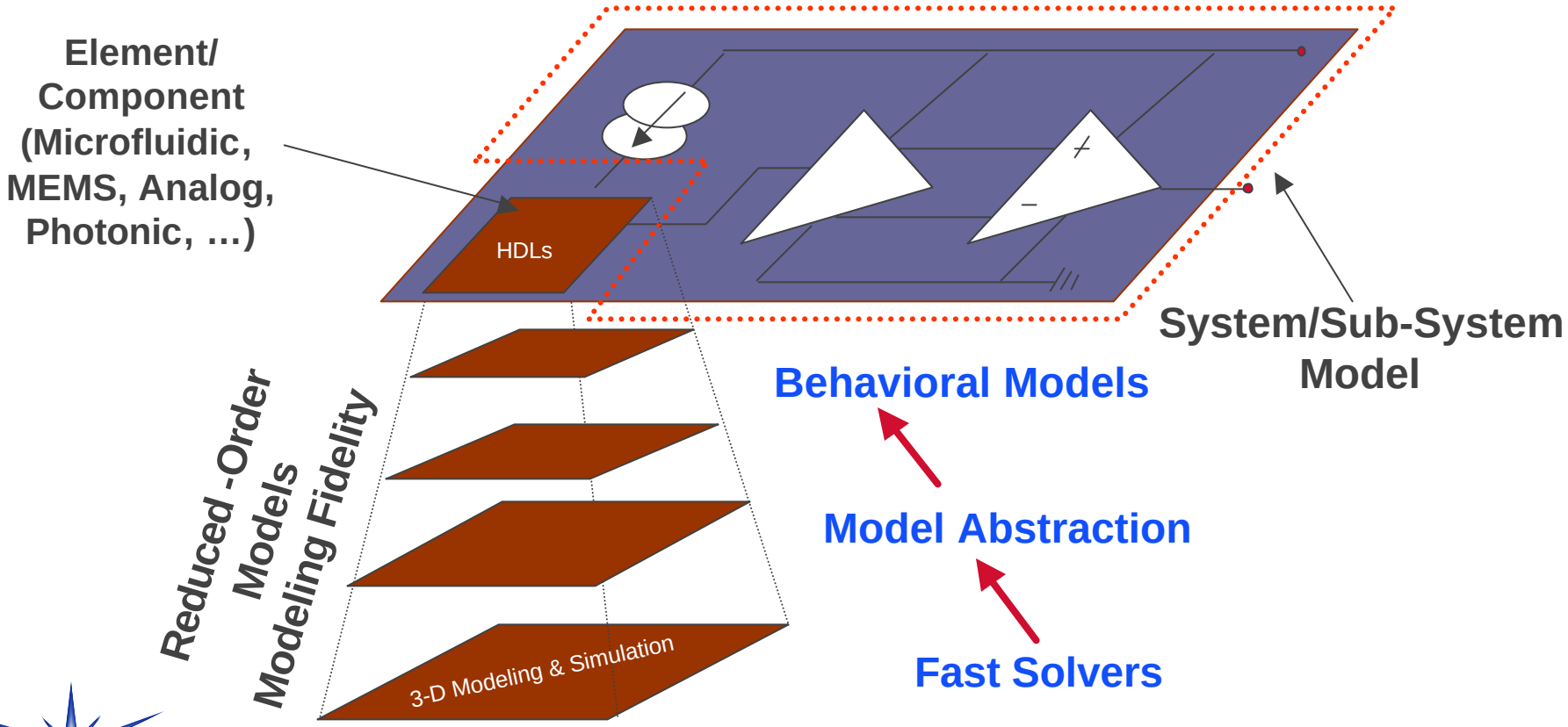
Integrated VCSEL-Detector Arrays



Lack of Automated Design Methodologies ; More of an ad hoc approach

Integrated System Analysis

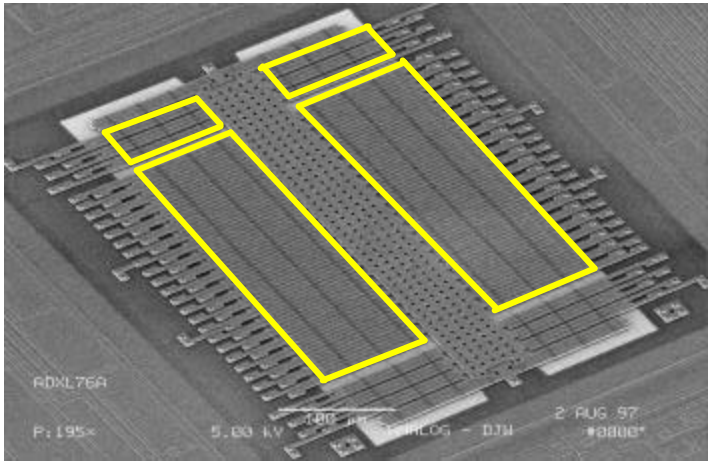
- **Development of reduced models and integrated system models for mixed technology microsystems**

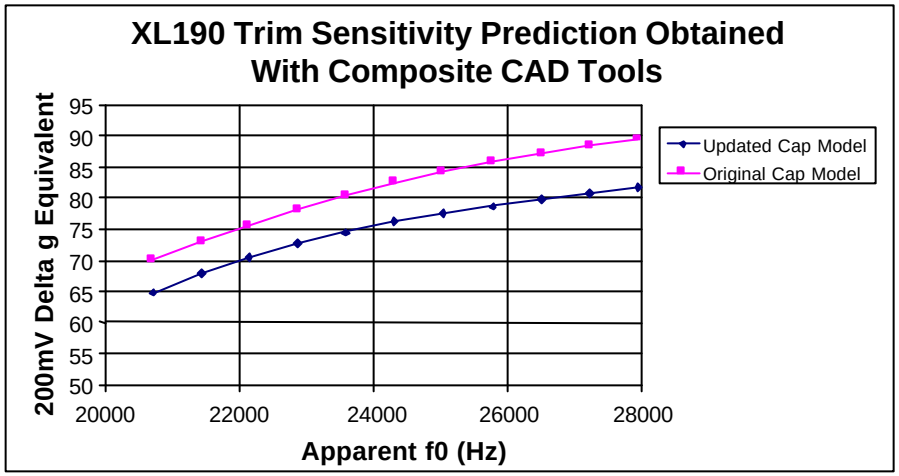


Linear as well as Non-Linear Systems !

Demonstration of Mixed Technology Design – Example 1

- Reworking the (Analog Devices) 50g Sensor into a 190g device

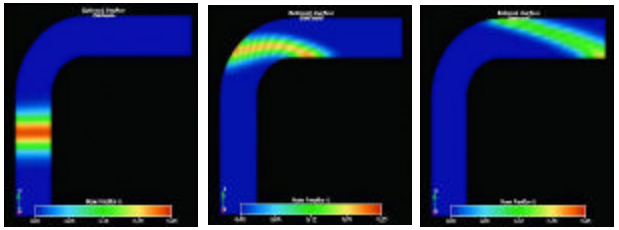




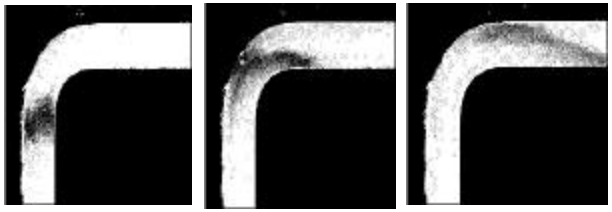
Full 3D simulation improved trim yield by 20% because of better sensitivity prediction.

- Accurate calculation of the trim factors for this particular device was only possible using the 3D electromechanical (Composite CAD) tools
- The trim factors are essential in order to trim the device accurately. Without the simulations, AD would not have a product

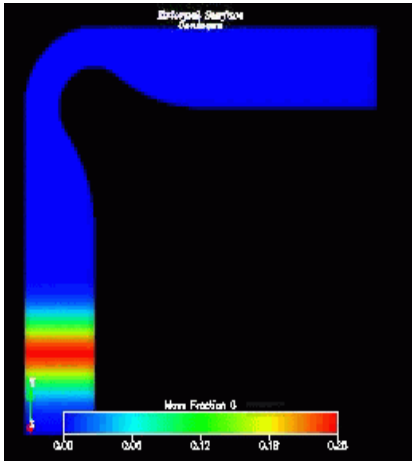
Demonstration of Mixed Technology Design – Example 2

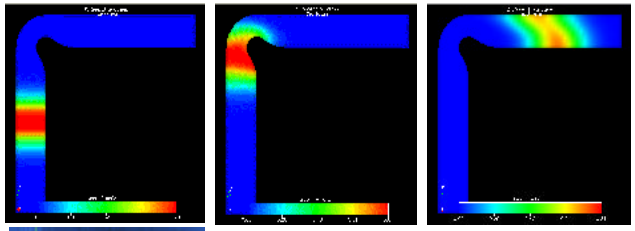


Simulation

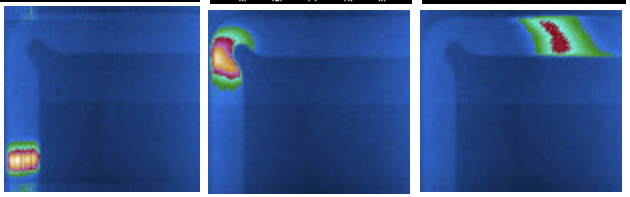


Experiment

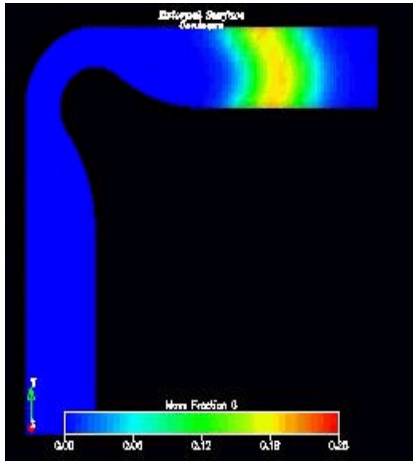




Simulation



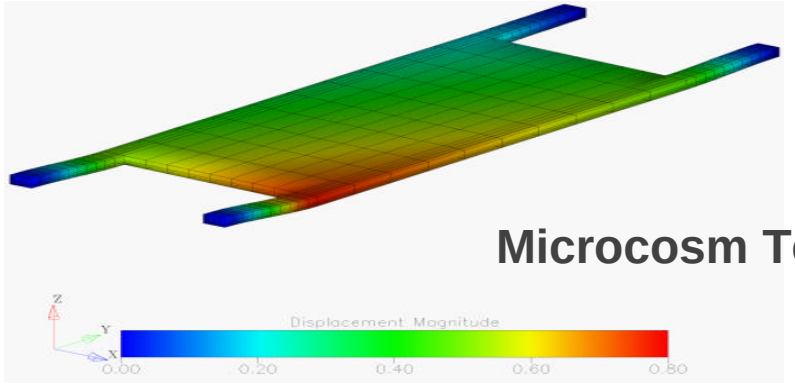
Experiment



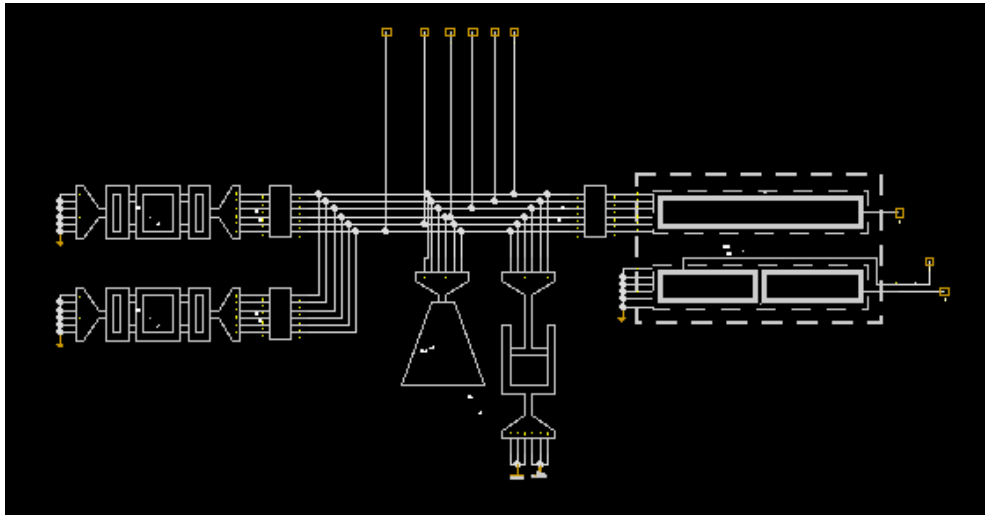
Stanford Microfluidics Laboratory

- **Simulation enabled development of a new design that minimizes dispersion in a miniaturized electro-osmosis process !!**

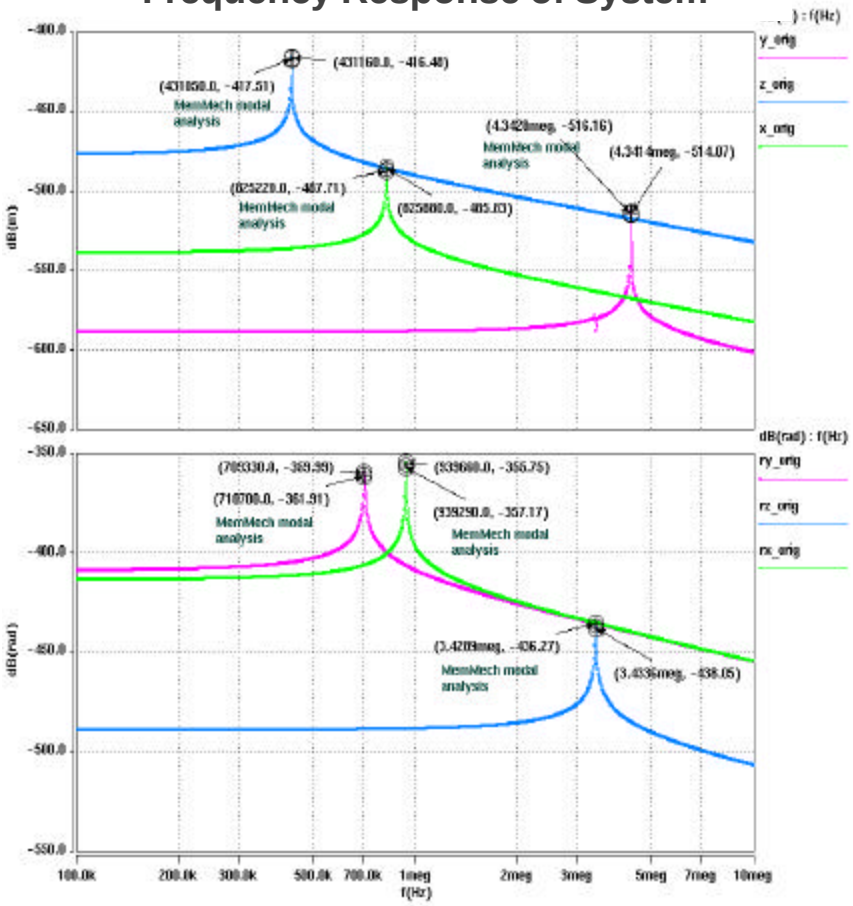
Demonstration of Mixed Technology Design – Example 3



Microcosm Tech.



Frequency Response of System



- Model reduction enabled orders of magnitude reduction in simulation cost without sacrificing model accuracy !

Focus Areas

- Quantitative models (scaling relationships and phenomenological models) for microfluidic devices, MEMS, photonic components, etc.

- Model abstraction/reduction and integration at the microsystem scale - **Integrated System Analysis**

Capability to design microsystems with a high level of multi-disciplinary integration – Enabling technology for exponential growth !!